THE POTENTIALITY OF NON-INVASIVE DIAGNOSTICS FOR THE INVESTIGATION OF A RENAISSANCE RELIGIOUS WALL PAINTING

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Abstract

In this contribution, the potentiality of multispectral imaging combined with in situ spectroscopy analysis will be tested on a religious wall painting located in a niche in Palazzo Chigi at Viterbo (Italy). The painting represents the Virgin with the Child and is attributed to the Italian Renaissance artist Antonio del Massaro, also known as Pastura. The painting has been recently and definitively dated back to the beginning of the 16th century; it has been recently examined by hypercolorimetric multispectral imaging, ultraviolet fluorescence photography and X-ray fluorescence spectroscopy, all performed on site in a totally non-invasive modality. The aim has been to investigate the artist's materials and to compare them with those of other studied wall paintings of the same author. The gathered information will be useful for a potential future restoration on the painting, which would be desirable given the poor conservation conditions.

Keywords: wall-painting, Pastura, Italian-Renaissance, imaging-techniques, cultural-heritage

1. Introduction and historical details about the painting and the artist

The analysis of art works is a fundamental process in the approach to the artefact from different points of view: 1) to know the constituent materials and original construction techniques and thus confirm the attribution of the work of art itself; 2) for the purposes of authentication of the works themselves, in case of doubt and this also presents an economic implication for those who market cultural heritage objects and for the museums that manage them; 3) to support restoration interventions on works of art, because nowadays it is essential to carry out pre-, during and post-restoration diagnostics in order to evaluate the quality of the intervention itself but also to direct it to the best by having a knowledge of the original materials and restoration products selected for

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restoration and treatments. It is significant that all professional restorers who are trained in higher education schools, universities and academies where there are master's courses enabling the profession of restorer of cultural heritage, consider diagnostics as fundamental and necessary to conduct the restoration in a correct way. Therefore, diagnostics has become, together with the historical, historical-artistic, archaeological study and the restoration itself, one of the cornerstones of the restorer's training in Italy.

In order to obtain information on the constituent materials and on the techniques of execution, many investigation techniques are available. These are often selected on the basis of the availability of individual laboratories, but certainly priority is given to non-invasive and non-destructive techniques that allow obtaining information without damaging the work of art which, by its nature, is unique and not reproducible [1-4].
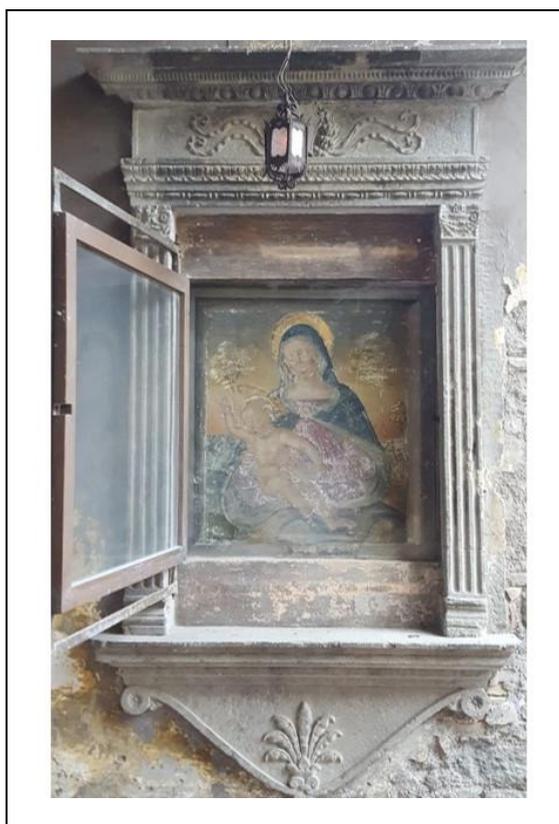

Figure 1. The wall painting representing the Virgin with the Child inside the niche in the porch of Chigi Palace. The photo shows the bad state of preservation of the painting.

For these reasons, in the present paper, the application of two non-invasive on-site techniques will be presented and shortly discussed. Specifically, an innovative hypercolorimetric multispectral imaging (HMI) technique and X-ray fluorescence spectroscopy have been used to investigate a 15th century wall

painting located in a niche in the porch of the historical Palazzo Chigi in Viterbo (Italy) in order to highlight the potentiality of non-invasive methodologies to gather information on artworks composition and state of conservation (Figure 1).

The painting has been attributed to the Italian Renaissance Master Antonio del Massaro, well-known as Pastura, and represents the Virgin with the Child [5]. To protect the painting a sort of window was installed to close the niche, creating some problems to perform the diagnostics campaign, as visible in the Figure 1.

Pastura was born in Viterbo, around 1450 AD, and his name appeared for the first time on 17th December 1478 among the signatories of the statute of the corporation of Saint Luca [6, 7]. In the Roman environment, he established his first relationships with Perugino, Pinturicchio, Antoniazzo and Melozzo, Masters of the Italian Renaissance [7]. There is no further news until 30th October 1489, when he received payment for paintings executed in the parapet of the choir of Orvieto cathedral. He remained in Orvieto until 1492 [7]. In the same year, Pastura had to move to Rome following Pinturicchio, who then undertook, working there until 1495, the decoration of the Borgia apartment in the Vatican [7].

The Roman activity of Pastura was wide: the Madonna delle scale in the Palazzo dei Conservatori and a fresco with the Madonna, Saint Francesco and Saint Chiara in Saint Cosimato, to cite the most relevant. Subsequently - perhaps still following Pinturicchio - he returned to Orvieto, where his presence is documented between the years 1497 and 1499. From 1504 to his death (around 1516) he was in Viterbo area where he realized other paintings [8].

The critics' unfavourable judgment on Pastura is justified by the lack of originality that characterizes his pictorial work: he in fact appears to be a faithful, but impersonal interpreter of the ways of Perugino and Pinturicchio. However, we must recognize a certain congeniality with the models to which he constantly referred, especially in the expression of a sweet and subtly pathetic feeling; Mancini had already noted that he "had a good attitude and expressed his emotions very well" [9]. However, Pastura's importance essentially consists in having contributed worthily to disseminating knowledge of the forms of fifteenth-century Umbrian painting in Lazio [7].

The artwork examined in the present paper has been attributed to Pastura by various authors, but only recently it was definitively established that it was a painting created by the artist around 1509, so it may be considered a later production [5]. The wall painting, now in the Chigi Palace, is considered by the art historians as a pretty artwork but seriously damaged (Figure 2).

It was detached on the 10th of December 1889 from the wall of an edifice belonging to the Chigi family and situated in the alley Fontanella del Suffraggio (Little Fountain of the Suffrage) [5]. The painting was never examined before the present paper and the results of the diagnostic campaign could be useful for a future restoration that is recommended to avoid further damage of the artwork.
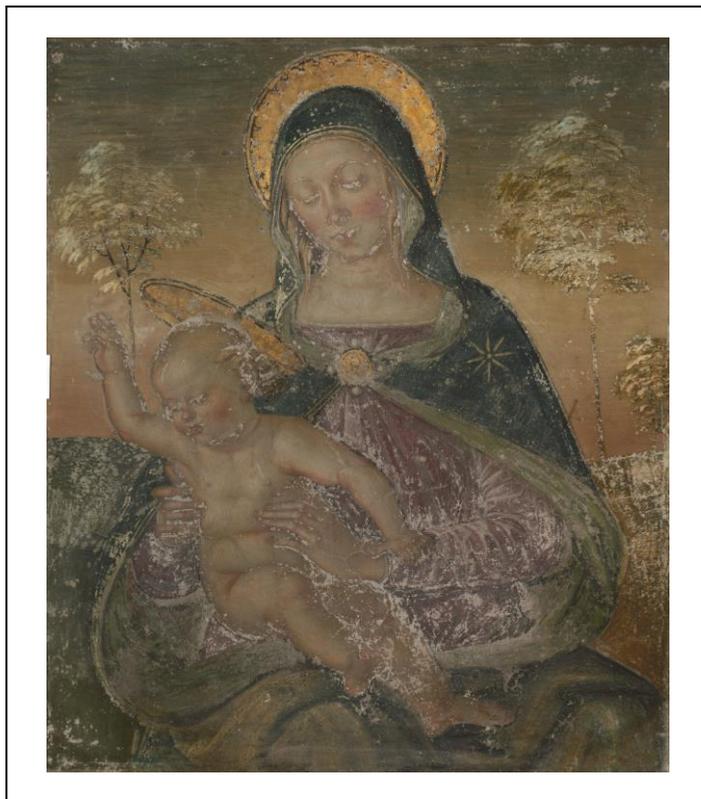
Figure 2. The calibrated RGB image of the wall painting representing the Virgin with the Child.

2. Experimental

2.1. *Hypercolorimetric multispectral imaging (HMI) and Ultraviolet fluorescence photography (UVF)*

Hypercolorimetric multispectral imaging is an innovative technique developed by the Italian society Profilocolore srl [10]. It is based on an acquisition system and two software tools for calibrating and processing the images, respectively. The acquisition system consists of a Nikon D810FR 36 megapixel camera, modified to obtain full-range spectral reflectance measurements. Lighting was obtained by xenon flashes after removing their front plastic lenses, thus also allowing the UV wavelength to be emitted. The UV induced fluorescence (UVF) was obtained by filtered led projectors as UV source and UV-IR cut filter (400-700 nm) in front of the camera. In order to obtain calibrated and so reproducible images, a number of white patches surrounding the object and of 36 patches colour-checkers built using colour samples from the NCS - Natural Colour System®© catalogue have to be add in the scene, as radiometric references. The spectral reflectance of the references was accurately measured in the range 220-1050 nm in Profilocolore laboratory,

with 0.7 nm accuracy (Instrument System Spectroradiometer CAS 140 CT and dark room). After the acquisition phase, the raw images are uploaded to the software SpectraPick® for the calibration procedure that allows for obtaining seven monochromatic images, 16-bit TIFF format, containing the spectral reflectance values at 350, 450, 550, 650, 750, 850 and 950 nm (these last three named IR1, IR2, and IR3 respectively), and a single AdobeRGB TIFF 16 bit colour image (Figure 3). The achieved precision across the whole 36 megapixels image is higher than 95% on the spectral reflectance images and colour error less than CIE2000 $\Delta E = 2$ for the colour image. The whole calibration and alignment process requires few minutes and can be performed in situ to check the quality of the results; in case of high error, it is possible to repeat the acquisition for improving the quality of the images.

After the image acquisition and calibration, the multispectral images were processed through the HMI software PickViewer®, also in this case developed by Profilocolore.
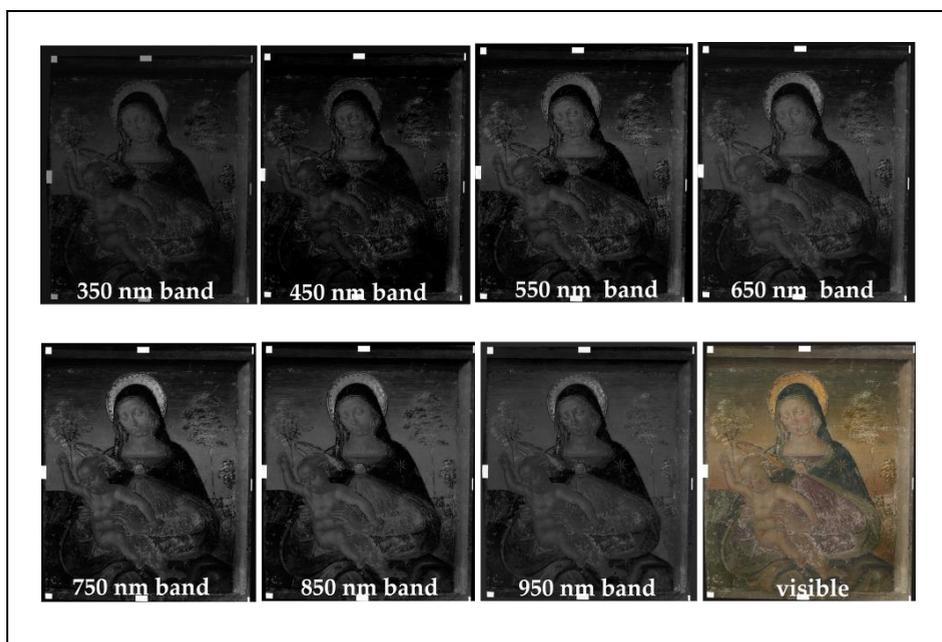

Figure 3. The seven calibrated bands and the RGB image obtained by SpectraPick® calibration software.

2.2. X-Ray Fluorescence spectroscopy (XRF)

X-Ray Fluorescence spectra were collected with a portable XRF spectrometer, Assig Surface Monitor II. The instrument is based on a silver anode as the excitation source. The measurements were performed under the following conditions: tube voltage 40 kV; tube anode current 76 µA, acquisition

time 60 s. XRF measurements were performed in a total of 10 points (X1-X10) on all the different colour of the painting (Figure 4).
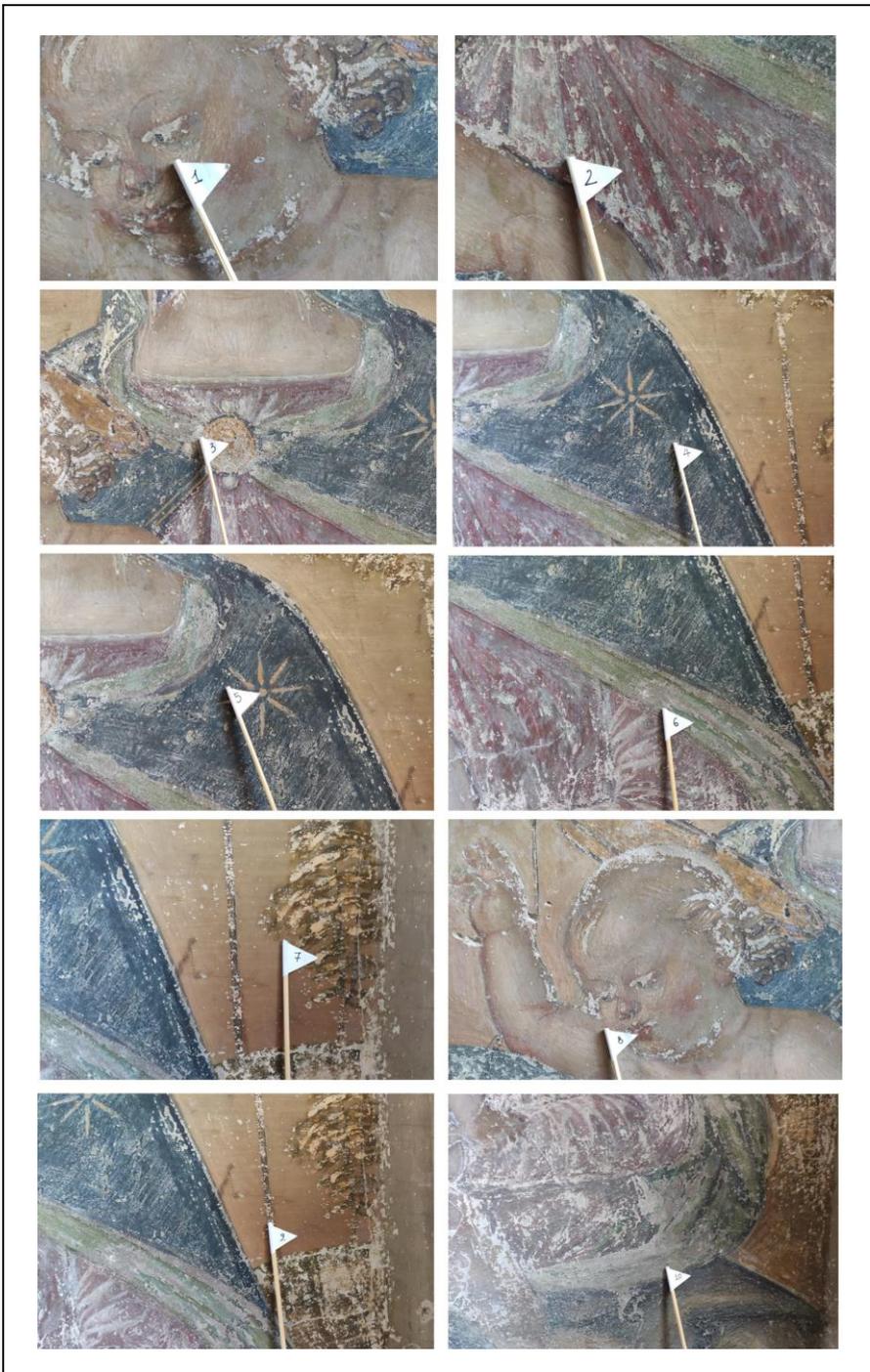

Figure 4. Details of the painting with the points of XRF analysis.

3. Results and discussion

3.1. Multispectral imaging by HMI

The calibrated images obtained by HMI can be used without any further processing such as the IR bands, that supply information on the underdrawings and possible pentimenti of the artist (Figure 5). In particular the images shown in the Figures 5 highlight the drawing used for obtaining details of the hair, of the haloes, of the hands.

Figure 5. IR2 band's details showing the Christ Child and the Virgin. The infrared reflectographic images highlight the drawing used for defining the halos, the garment folders, the hands and the hair, and also the high quality of the painting.

Figure 6. The UV band obtained by HMI at 350 nm and the ultraviolet fluorescence image.

To investigate the state of conservation of the painting surface, the ultraviolet images are generally very useful [11]. In the case of the wall painting by Pastura, the reflected UV and UV fluorescence photos are shown in the Figure 6.

Both the UVR band and the UVF image highlight the surface abrasion of the painting layer mainly concentrated on the Virgin dress. The UVF image shows a pale blue fluorescence on the left side in correspondence of the Child hand that could be associated to a residue of past restoration material; it may also be due to the detachment process of the painting.

Concerning the HMI processing, one of the most useful applications in cultural heritage is the infrared false colour (IRFC) transformation of the acquired RGB image. This can be obtained by simply changing the RGB channels and combining them with one of the IR: R (red) channel is moved to IR2 or IR3 (in our case IR2), the G (green) channel is moved to R, and the B (blue) channel is moved to green (Figure 7).

The observation of a surface in IRFC could give general information about pigment composition and distribution [12], even if the result gathered through infrared false colour processing should be confirmed and supported by other techniques such as X-ray fluorescence and/or micro-Raman spectroscopy. Moreover, pigments of different composition could give similar IRFC response making difficult an attribution with this technique alone. After having applied the 'False Colours' algorithm of PickViewer®, the result can be observed as in Figure 6, otherwise the IRFC image may be exported and studied in comparison to the RGB one, as shown in the Figure 8.

The mantle of the Virgin and the upper part of the background appear with a dark blue colour in the IRFC image suggesting the use of a copper-based pigment, it may be supposed azurite. The blue colour is no more visible in the RGB image probably due to the bad state of preservation of the painting and to the almost complete loss of the copper-based pigment that was usually applied by a secco technique over a black or dark red setting layer [13].

The use of azurite seems usual in Pastura, in fact this pigment was detected also in another detached wall painting attributed to the artist, i.e. in the Virgin garment and in the background of a lunette depicting Madonna and Child enthroned between the angels and the Saints Jerome and Francis [14].

The other pigments give typical responses of ochre and earths that could be supposed the materials used for the wall painting [15, 16]. This assessment is confirmed by the comparison of the RGB image with the ultraviolet false colour processing (UVFC) that shows the typical violet response of iron-based pigments, visible in the background, in the garment and in the haloes (Figure 9).

The UVFC output can be obtained by simply changing the RGB channels and combining them with UV one: R (red) channel is moved to G (green) channel, the G channel is moved to B (blue), and the B channel is moved to UV.

Another useful tool of PickViewer® is the 'Spectral Similarities' that can be performed by choosing the reflectance or the colour to obtain the similarities maps. These maps show the distribution of a selected area of the painting (3x3

pixels or higher, chosen by the user) in terms of analogies in colour or in spectral reflectance. For example, a point was chosen in the upper part of the background in order to verify the similarity with the blue of the Virgin mantle. The result of the 'Spectral Similarities' tool is displayed in the Figure 10.
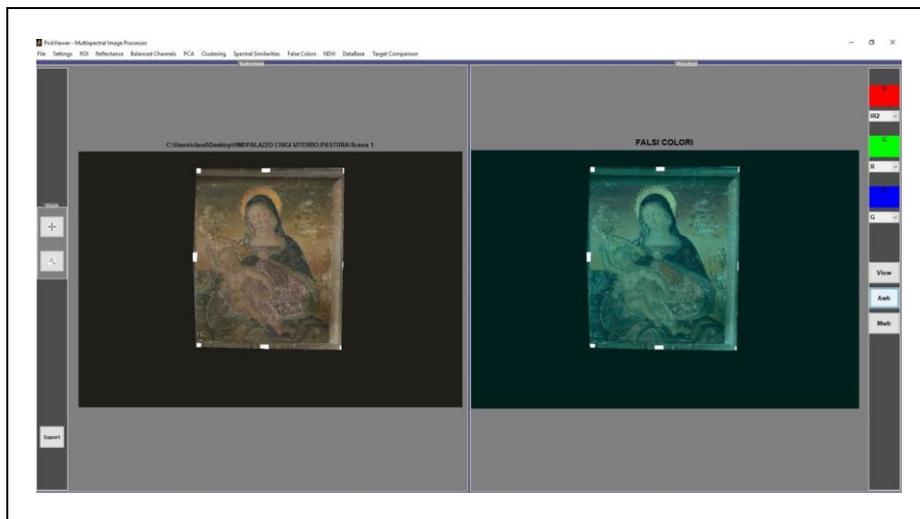

Figure 7. The graphic user interface (GUI) of the software PickViewer®. In the left window the RGB image of the painting can be seen and used for selecting region of interest (ROI), pixels, colours, etc. In the right window the result of the processing chosen is obtained. In this case, the infrared false colours (IRFC) by using the IR2 band (see the right upper part of the software bar).

Figure 8. The comparison between the calibrated RGB image (A) and the IRFC output (B) after the 'False Colours' algorithm application inside PickViewer®.

Figure 9. The comparison between the calibrated RGB image (A) and the UVFC output (B) after the 'False Colours' algorithm application inside PickViewer®.
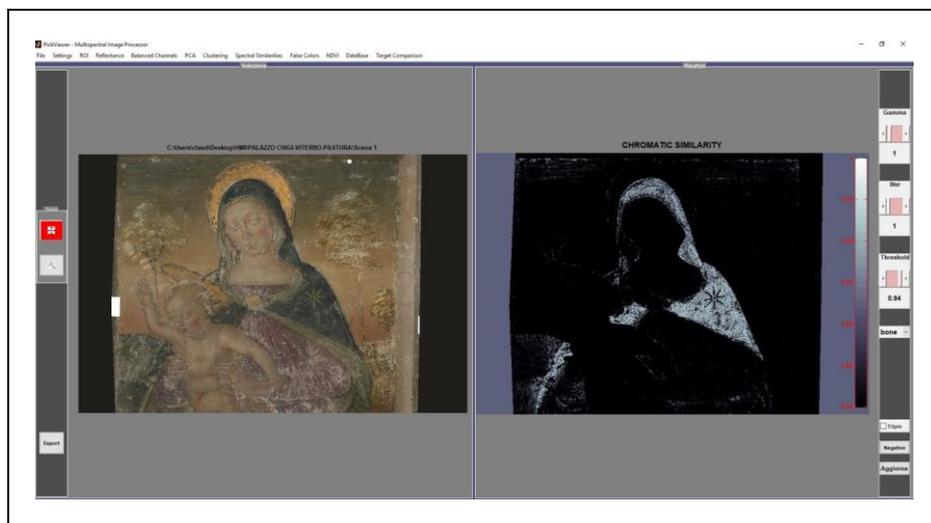

Figure 10. Application of the similarities tool to a 3x3 pixels area in the upper part of the background (white dot in the RGB image). In this case, the similarity is calculated by considering the chromatic parameters of the selected point. In the B/N image on the right the white pixels have high chromatic similarity whereas the black ones have no similarity.

The result of the 'Spectral Similarities' tool clearly highlights the distribution of the blue colour and the analogy between the sky in the upper part of the painting and the Virgin dress, confirming the use of the same pigment, probably azurite.

Other maps were created for the colours visible in the painting such as, for example, the red brown of the Virgin's dress (Figure 11). The result shows that the dark red colour is limited to the garment of the Virgin and to some parts of the contour of the Child's body.
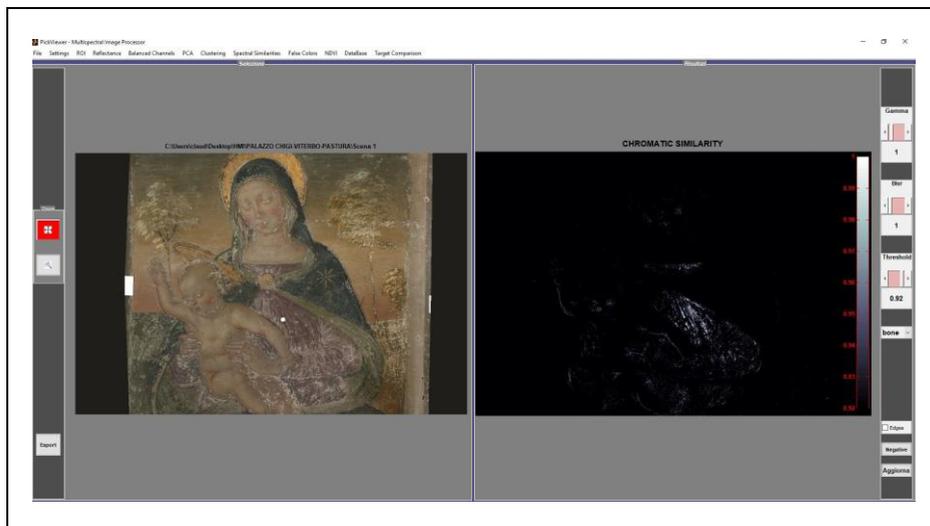

Figure 11. Application of the similarities tool to a 3x3 pixels area in the red-brown dress of the Virgin (white dot in the RGB image). In this case, the similarity is calculated by considering the chromatic parameters of the selected point. In the B/N image on the right the white pixels have high chromatic similarity whereas the black ones have no similarity.

The 'Spectral Similarities' tool revealed a powerful instrument to map the distribution of the pigments, very useful to address the point analysis by various possible techniques, such as XRF spectroscopy applied in the present study.

In order to confirm the presence of azurite and to make hypothesis about the other pigments' composition, XRF analysis was performed on ten points of the painting's surface (as shown in the Figure 4). The results of XRF analysis are summarised in the Table 1.

The presence of copper (Cu) in various points of the painting, with much higher counts on the Virgin's dress, confirms the use of azurite as blue pigment. This was probably applied by a secco technique on a ground layer that is black in the garment and yellow in the sky on the background. Being applied by a secco, azurite was almost completely lost from the painting, but several traces are still present and the XRF spectrometer was able to detect them.

Calcium (Ca) has been revealed in all examined points because it is the main constituent of the plaster and of the binder for the fresco technique. Where present in higher counts, calcium is probably associated to calcium carbonate white used to lighten the colours.

Table 1. Results of XRF analysis expressed as main detected chemical elements and counts per second (cps) measured by the detector of the spectrometer.

XRF Point	Description	S	K	Ca	Fe	Cu	Rb	Sr	Au	Pb
X1	Flesh of the			2996	337		59	188		
X2	Red garment	60		2487	2109		88	268		245
X3	Gold colour	69		1564	676	146		221	720	514
X4	Blue of the Virgin mantle	84		2244	455	5162	86	232		
X5	Star on the Virgin mantle	59		1535	240	6230	111	137	558	101
X6	Green of the garment	77	115	1647	1243	324	65	244		90
X7	Yellow of the tree on the	127		3044	636	197	100	315		103
X8	Lips of the	58		2962	667		76	268		
X9	Background	105		4219	533	171		319		70
X10	Dark green	52		2299	558	255	95	266		76

The other chemical element detected in all points is iron (Fe). Iron is the main element and chromophore of iron oxide pigments (yellow ochre, hematite, green earths, etc.), but also a constituent of the minerals added to the lime to produce the plaster, so Fe is usually found in wall paintings.

Anyway, the presence of iron in the yellow, red, green colours confirms the use of ochre and earths in the Pastura's wall painting.

Rubidium is another element usually present in the mineral of the plaster, and so it is normally found in XRF analysis of wall paintings.

Sulphur (S) and strontium (Sr) are generally associated to the presence of sulphates that could be considered as materials introduced during the detachment process or salts migrating from the cement wall. These usually create surface salt efflorescence on the painting whose presence is dangerous for the conservation of the artwork.

Gold (Au) has been detected in two points (X3 and X5) indicating the use of this precious element for the brilliant parts of the decorations. Lead (Pb) was also found in seven points suggesting the use of pigments containing this element. Lead can be associated to pigments used in the ground layer of the gold leaf with siccative function and further as pigment.

Finally, in the green point X6 potassium was also measured. This element is associated to the mineral typical of the green earths (celadonite and glauconite).

4. Conclusions

In this contribution the potentiality of Hypercolorimetric multispectral imaging (HMI) and portable X-ray spectroscopy was investigated on the wall

painting preserved in a niche in Palazzo Chigi at Viterbo (Italy), attributed to the Italian Renaissance Master Antonio del Massaro known as Pastura.

The wall painting, dated back to the beginning of the 16th century, is located in a little niche in the porch of the inner courtyard of the palace, closed by a window, after its detachment occurred in 1889.

The analysis, performed in a totally non-invasive modality, allowed for obtaining several preliminary information about the painting materials and technique, that could be implemented by future on-site and laboratory examination if necessary to support the desirable restoration. First of all, the analyses revealed the use of pigments applied by a fresco, such as ochre and earths, but also by a secco, such as azurite, a pigment widely used by Pastura for wall paintings; moreover, the presence of gold testifies the preciousness of the painting.

The detachment of artwork and the unsuitable conservation environment caused the loss of azurite and the presence of salt efflorescence on the surface, together with dirt and various deposits.

The multispectral investigation highlighted a refined drawing and elegant details of the painting that should deserve attention and efforts to restore them.

In fact, a restoration intervention has been recommended to the owners of the Palace: this will be useful to preserve and valorise the artwork with the aim at transmitting it to the future generations.

Acknowledgement

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